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Effects of the Financial Crisis on Stock Market of the Czech Republic and Spain

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Declaration of Authorship

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Abstract

The paper analyzes effects of the financial crisis on stock market of the Czech Republic and Spain. We employ BEKK-GARCH model in order to study volatility spillovers and transmissions from the US stock market to stock markets of the Czech Republic and Spain. The multivariate GARCH models results show statistically significant, but relatively small, almost irrelevant volatility spillovers from the US stock market to stock markets of the Czech Republic and Spain. The Czech stock market exhibits higher conditional correlation coefficient than the Spanish stock market.

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CHAPTER 1

1. Introduction

The global financial crisis of 2007-2008 is supposed by the majority of economists to be the worst financial crisis since the Great Depression of the 1930s. It caused danger of overall failure of major financial institutions, support of banks by national governments and crash of stock exchanges worldwide. The financial crisis performed fundamental function in the collapse of primary businesses, downturns in consumer wealth and slow-down in economic activity running to world slump and raising the European sovereign-dept crisis.

The objective of this thesis is to study the effects of the crisis on stock markets of the Czech Republic and Spain. We will analyze stock markets returns of the Czech Republic and Spain. For the aim of our study, PX (Prague Stock Exchange) and IGBM (Madrid Stock Exchange) indices are used. We will find out whether relevant coordinated movements among the markets exist by comparison with US stock market. The NASDAQ 100 index is used as landmark for US stock market shifts and fluctuations. We will compare conditional correlation among NASDAQ 100 index and PX, and IGBM indices. Multivariate GARCH model is employed to analyze volatility spillovers and transmissions from US stock market to Czech and Spain stock markets.

The thesis is structured as follows: Chapter 2 represents the review of literature regarding former studies where BEKK-GARCH model is employed. Chapter 3 describes stock exchanges of Prague, Madrid and New York. Chapter 4 presents modeling volatility. Chapter 5 introduces the initial analysis. Chapter 6 represents the findings and concludes.

CHAPTER 2

2. Literature Review

Bollerslev (1990) applies multivariate heteroscedastic interval sequences process within time inconsistent conventional deviations and covariances and constant conditional interrelations. The model is proposed as development of Seemingly Unrelated Regression (SUR) for testing heteroscedasticity. The conventional deviations are parameterized like an univariate Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. The process is employed for a group of five European/US dollar currency rates after establishment of European Monetary System (EMS). The results show significant increase in common shifts among currencies in period after the establishment of EMS compared to the period before the establishment of EMS.

Karolyi (1995) analyzes robustness of yields and fluctuation in the short term of shares at Toronto and New York stock markets over the period from 1981 to 1989. He find out that implications concerning the relevance and consistence of yield trend-setting which arise within both markets and which pass to second market to be subject to significantly of modeling fluctuation of market robustness. Furthermore, much inferior market robustness within yields and fluctuation predominate throughout subsequent subintervals and particularly about Canadian shares dually recorded at New York. Inferences about international facilities evaluation, hedging policies and regulatory courses are argumented.

Longin and Solnik (1995) analyze interrelation of monthly surplus yields for seven principal states for interval from 1960 to 1990. They work out that volatility of covariance and interrelation matrices through intervals. Certain development within conventional covariance framework is taken up by multivariate GARCH process with invariant conventional interrelation. Nevertheless peculiar variation tests show dismissal of invariant conventional interrelation premise. A specific shaping of conventional interrelation exhibits a raise of international interrelation among markets through the last three decades. Furthermore they find out that interrelation increases within time of tremendous instability. Particular initial substantiation indicates that economical variables for instance rate of interest and returns of dividends include news relevant for future fluctuation and interrelation which is not included into former yields solely.

Sheedy (1998) studies interrelation within main foreign exchange markets for the period from 1980 to 1996 beyond risk naturalization. He find autoregressive framework of currency interrelations, appropriate to those about deviation. Nevertheless, substantiation about relationship among interrelation and variability, market outcomes within variability and interrelation asymmetry at risk adapted base is implausible. Analysis exhibit unstable worthiness of composite multivariate determinations constructed to take up those effects. Further compressed determinations principally exert optimum, ensured that they take up instability grouping. Moreover, incorporation of hedging conclusions and means distribution are studied.

Kroner and Ng (1998) make comparison of limitations on influence of last shock on projected covariance matrix, among four multivariate GARCH models and establish an aggregate of vigorous relative momentum analyses to diagnose misspecification. They show that selection of multivariate variability process may run to significantly diverse implications into each promotion that includes projecting dynamical covariance matrices. They consequently establish basic model that incorporates the four multivariate GARCH models. Their model is employed to analyze dynamical interrelation among mayor and small company yields.

Gagnon et al (1998) analyze dynamical and portfolio results into multi currency hedge puzzle that includes risk decline and speculative parts for inquiry of futures. They shape common development of everyday spot portfolio yields log variations of relevant prices of futures within trivariate GARCH model admitting tine varying volatility among the elements of the framework. Hedge results are estimated from risk minimizing and value aspect. They find that accounting for portfolio results into developing multi currency protection run to effectiveness and value benefit.

Gulen and Mayhew (1999) study equity market variability ahead and beyond the establishment of stock rating futures market in a few states employing different models about testing for conventional heteroscedasticity, asymmetrical variability reactions and common momentum of indices of all the states within the global market index. Their results show that futures market is linked with a growth of conventional variability in Japan and US, as well as no considerable variability result in almost all other states. Furthermore, they find evidence of raise within conventional variability among state and global yields.

Kearney and Patton (2000) study the transmission of currency rate fluctuation into the European Monetary System (EMS). They form sequences of three, four and five variable multivariate GARCH specifications of currency rate fluctuation transference through the major EMS currencies inclusive the national currencies of Germany, France, Italy, British pound as well as European Currency Unity. Using data for the period from April 1979 to March 1997 they projected the models without entailing standard limitation of invariant interrelation. In the estimation of the model they employ Baba, Engle, Kraft and Kroner (1990) BEKK parameterization of the multivariate GARCH model. Their results exhibit the essentiality of verifying about determination dynamics within multivariate GARCH shaping. They work out that German currency performs fundamental role withinin conditions of instability transference and that enhanced interim group decreases studied instability transference. Furthermore they find out that models which they evaluate on everyday data alter substantially between specifications. Models they evaluate using weekly data show practically no instability transference. They find out for the clearing significance of central banks for time extent unconditional within the intervention policies of currency rate fluctuation.

Tse (2000) establishes Lagrange Multiplier (LM) for testing the hypothesis about invariant interrelation within multivariate GARCH process. The limitations comprised in the model including invariant interrelation GARCH process are analyzed. The test is computationally appropriate and claims valuations of invariant interrelation model merely. Taking into consideration ultimate model characteristics, Tse presents several Monte Carlo effects. He makes comparison between LM test and Information Matrix (IM) test. LM test shows decent influence in spite of choices taken into consideration and is further vigorous to non-normality. They exert test to stock exchange yields, foreign currency returns and prices of spot futures. Tse finds out time inconsistent interrelations among national stock exchanges yields and invariant interrelations of foreign currency and spot futures.

Ng (2000) analyzes volume and fluctuation of instability overflows from US and Japan to six stock markets of the Pacific Basin. He builds an instability overflow model that enables unanticipated yield of each distinct stock market of the Pacific Basin be moved by the worldwide shock from US, territorial shock from Japan and municipal specific shock. The results show that throughout and across the influence of global factors, considerable overflows from locality to majority of Pacific Basin stock markets. Deregulation cases,

currency rate conversions, market volume and state trust bonus are asserted to influence relating significance of global and local stock markets factors.

Kasch-Haroutounian and Price (2001) analyze shaping variability in four Central European financial markets. The pattern considers whole earlier supported features of implicit allocation of share yields typically run to support employment of the GARCH type of models of conventional variability. They take into consideration univariate and bivariate GARCH models. Powerful GARCH results are evident into each series studied. Valuations of asymmetric models of conventional variability exhibit relatively poor witness of market asymmetry. The outcomes of multivariate determinations of variability are important for comprehension the sample of information streaming among markets. The invariant interrelation determination implies substantial conventional interrelations among Czech Republic and Hungary, and Poland and Hungary respectively. Employing BEKK model, they find no variability overflows from Poland to Hungary. The results exhibit variability overflows in reverse way.

Engle and Sheppard (2001) employ Dynamic Conditional Correlation Multivariate GARCH models in order to estimate huge time inconsistent covariance matrices. They exhibit that issue of multivariate conventional deviation valuation could be solved with using univariate GARCH model in order to estimate conventional interrelation valuator. Standard omissions about interrelation fundamentals have to be changed. They employ model about conventional covariance valuation for maximum of 100 assets using 2 indices and implement determination tests of valuator. Evidence is found of very good commitment of conventional interrelation valuator. This valuator is simply practicable.

Ding and Engle (2001) propose new type of transverse Vech model. Satisfactory terms for parameter matrices are determined to secure real definiteness of covariance matrix from new model. They offer several diagnostics tests for multivariate ARCH processes. Tests enable to identify different models which are misspecified by analyzing orthogonality of quadrate standardized residuals. Minor pattern features of test are verified by commitment of minor Monte Carlo analysis. Experiential pattern is specified like direction valuation of the model and choosing multivariate structure. They find that standard conventional interrelation model works relatively fine.

Tse and Tsui (2002) offer multivariate generalized autoregressive conventional heteroscedasticity (MGARCH). Their model involves time varying interrelations. They

modify vech introduction established on conventional interrelations and deviations. Conventional interrelation matrix is assumed to conduct autoregressive shifting moderate type of analogue, since every conventional deviation condition is supposed to track an univariate GARCH establishment. Their model keeps insight and explanation of univariate GARCH process and further suits positive determined term like established within invariant interrelation as well as BEKK model. They present Monte Carlo results within ultimate subject allocations of maximal probability valuation of floating interrelation MGARCH process.

Caporale et al (2002) study common linkage among currency rates and equity prices variability into four states of Eastern Asia. They employ GARCH model with appropriation of BEKK specification purposely to study consequences within instability as well as significant null limitation within conventional divergence criteria. The results exhibit that equity prices into prior crisis pattern have positive effect on the currency rates into Thailand and Indonesia and negative effect on the currency rates into South Korea and Japan. They find reversible overflow results into Thailand and Indonesia as a consequence of the crisis in Eastern Asia.

Weide (2002) offers new sort of multivariate GARCH model where potentially huge covariance matrix could be parameterized by relatively huge extent of space. Moreover, valuation of fundamentals stays practicable. This new model is supposed to be factual generalization of GARCH model. He presumes to utilize implicit information that amount of parameters which have to be evaluated by facilities of relative information is higher than half, purposely to shrink convergence obstructions of valuation algorithm.

The model upholds the presumption that examined variables are shifted by several non related parts, connected by linear portfolio. Purposely to type the parts, he requires invertibility of common matrices. The zero premise supposes orthogonal matrix which soley comprehends minor set of potential invertible matrix. Furthermore, yet if matrices are in fact orthogonal, valuator suggested by GARCH is unable to disclose constantly. GARCH process regards invertible matrices like potential relation that would be parametrized into that mode which it is not anticipated to implicate valuation whereas eliminating identifying issues.

Baur (2003) employs modifiable dynamical interrelation model which parameterizes the conventional interrelation straightforwardly and excludes different weaknesses of substantial multivariate GARCH process. He takes into consideration everyday yields of four equity market indices and finds out that interrelations show various levels of consistency and

various asymmetrical responds to shocks compared to deviations. The results also exhibit that interrelations do not enhance at all time within common inverse shocks.

Chan (2003) employs bivariate increase model to analyze increase momentum within foreign currency yields. His model expands multivariate GARCH parameterization to involve bivariate interrelated increase operation. The relative covariance matrices have BEKK frame, whereas bivariate increases are directed by interrelated bivariate poisson part. Employing everyday information he retrieves substantiation of self sufficient currency determined increases and increases mutual to currency rates of Japanese yen and Canadian dollar versus US dollar. Chan infers by analyzing time varying framework for approach of increases which relieves the supposition of standard restrained increase interrelation established by interrelated bivariate poisson operation.

Yang et al (2003) analyze values of futures and fluctuation transference between three huge corn manufacture and export estates, the European Union, United States and Canada during six year period from 1996 to 2002. The value transference sample exhibit that US values are less impacted by Canadian values than Canadian values are impacted by US values. European Union is significantly self relied and could exhibit certain impact on US values into long term but not inversely. The fluctuation transference sample, nevertheless, exhibits that fluctuation is transferred from European Union and Canada to United States but not inversely. The instability is further transferred from European Union to Canada but not inversely. The results show no significant direction function within international corn markets. Furthermore, every market shows characteristics of value direction to certain scope.

Benavides (2004) studies variability correctness of variability estimation models taking into consideration price returns of futures of wheat and corn. He employs an alternative indicated, complex estimation, univariate GARCH and multivariate ARCH model with adoption of BEKK representation. The complex estimation model comprises time sequences and alternative indicated variability estimations. They find evidence that the complex estimation models are more correct than the option indicated models. They suggest that if interval sequences and alternative indicated data is disposable, complex estimation model to be applied.

Chong (2004) parallels everyday currency rate worth at risk forecast resulted from econometric methods with forecasts implicated by values of market selections. They apply univarate GARCH process and multivariate GARCH process together with common primeval and progressively weighted flexible median process. The results that over stable intervals,

implicit method inclines to overrate price at risk, therefore over distributing assets. Nevertheless, over impetuous intervals, it shows lower responsiveness than GARCH models, following to under-distribution of assets and bigger amount of downfalls. Therefore their basic inference, which is relevant for risk operation, is that anticipations of market of fluctuations and interrelations, like specified from values of market option, could not be optimum means for specifying price at risk. Thus, variant models for evaluating variability need to be taken into consideration.

Karanasos and Kim (2005) in order to explore linkage among real and nominal volatility within G3, apply bivariate GARCH approach of yield and inflation increase. They employ evaluated model to examine for reversible results and evolve relative divergences of yield and inflation increase like substitutes of yield and inflation volatility. Their work upholds few relevant implications. Over the whole time interval from 1957 to 2000, they do not find any backward linkage among real and nominal volatility. About USA during interval from 1980 to 2000, they find substantial influence of inflation variability on yield variability. For Japan over the period from 1980 to 2000, the find positive influence of yield volatility on inflation volatility. Lastly, for each of observed countries, for the period from 1960 to 1980, they do not find presence of any influence in one or other way.

Baur (2005) argues major multivariate GARCH processes and concentrate on BEKK approach. He applies Flexible Dynamic Correlation (FDC) approach that parameterizes conventional interrelation straightforwardly and removes any weaknesses. Foremost, amount of exogenous variables within interrelation standardization may be flexibly enhanced devoid threatening the unrestricted covariance matrix. He uses yields on every day and monthly basis of several foreign stock exchange indices and finds evidence that interrelations assert divergent rates of consistency and various asymmetric responsiveness to shocks than deviations. Furthermore, he discloses that interrelations do not enhance constantly within common negative shocks inferring validity for portfolio variety.

Altay-Salih et al (2003) take into consideration restricted non-linear programming perspective of GARCH variability valuation models. The models are frequently introduced to reviewers like unrestricted optimization models within recursive conditions while they in fact decline within range non-salient non-linear programming. The find that restricted non-linear programming is useful practice for GARCH process particularly for trivariate and bivariate conditions, since they propose considerable progress into efficiency of optimization puzzle

commitment through transverse VECH and BEKK interpretations of multivariate GARCH process.

Grier and Grier (2006) employ enhanced multivariate GARCH model of production and inflation increase in Mexico. Their results exhibit that inflation volatility has considerable impact on growth, creeping inflation does not have straight-out impact on production enhancement, demerit impact of the total result of mean inflation on production increase in Mexico. The mean inflation is dangerous to growth of Mexico owing to the influence on inflation volatility. The presidency selection period in Mexico substantially increases inflation volatility and has demerit impact on production increase.

Cotter and Stevenson (2006) employ multivariate GARCH model in order to analyze instability in real estate investment trusts (REITs). They study yield and variability relationships among REIT branches as well as the impact different sequences of US shares. The investors have incentives to insert time varying variability and interrelations into the variety of portfolio. They find evidence of variation in the results when greater frequency data on daily basis is analyzed, compared to data on monthly basis which is usually employed within present literature. The relationships into the REIT branch as well as among REITs and linked branches for instance worth shares are inferior to those which are frequently find in monthly researches. The wide market manifests more power within everyday occasions.

Chen et al (2006) analyze two-sided linkages among three couples of stock exchanges, Chinese and Indian stock exchanges, US and Chinese stock exchanges, as well as US and Indian stock exchanges. In order to analyze the incorporation movements among stock exchanges, they employ slightly incorporated vector linked model. They examine overflow outcomes by expanding their model within multivariate GARCH establishment. They find evidence of minor incorporation of all three couples of stock exchanges. The results show a fundamental contribution of the US stock exchange into linkages within stock exchanges of China and India, as well as an interactive linkage among the letter two stock exchanges.

Patton (2006) applies model of reliance to examine asymmetry among the Japanese yen and the German mark, within sense that diverse interrelation rate is inserted in the time of common increase towards the US dollar counter time of common decline. They take into account development of copulas theory to enable about provision variables and apply to build resilient model of relative relationship framework of the currency rate. They disclose proof

that US dollar-Japanese yen and US dollar-German mark currency rates are less correlated in time of appreciation versus US dollar compared with time of depreciation.

Soriano and Climent (2006) study conditional significance of estate against industry results on shares yields, like reverse to significantly studied state against industry results. The pattern incorporates interval beyond cracking of technology bladder. Furthermore, fluctuation transference samples are studied into industry crosswise estates to examine if the same relations retrieved within total stock exchange indices obtain on industry rank. They find predominance of estate results in spite of industry results, unless throughout the bladder interval. The effect of fluctuation transference study implies the relevance of overflow to be subject of industry.

Michayluk et al (2006) create synchronic valued index of securitized assets recorded on London Stock Market and New York Stock Market. They analyze activity news trends among both markets by using indices. Studying yields presence, asymmetric fluctuation overflow results and exceedance interrelations, the find that factual assets market in UK and US undergo substantial interplay on everyday base when synchronic valued information are used. The results are various when close to close yields are analyzed, indicating that employment of close to close information may misinterpret real momentum which gets among both markets.

Li (2007) analyzes the relationships among two stock markets in China and stock markets of Hong Kong and US applying multivariate GARCH model. They employ asymmetric GARCH model with four variables to clarify about accuracy supported within stock price indices and examine for transfer of yields and instability through markets. He does not detect some proof of direct relationship among US stock market and stock markets in China. However, he detects proof of unidirectional instability overflows from stock market of Hong Kong to the stock markets of China. Anyway, the volume of fluctuation relationships among China and Hong Kong is modest, signifying low unity of the stock markets of China within local mature market. Inference of low unity is that foreign investors would take advantage from decline of risk of entire portfolio within putting Chinese shares into investment portfolio.

Lane and Saikkonen (2007) employ GARCH process and apply examination methods for controlling the accuracy of the amount of elements. Maximum probability valuation of GARCH process is common since computationally easy primary valuations are achieved. The combination of Gaussian apportionments is contemplated yet to conditional Gaussian

probability. Several parameters of conventional covariance matrix which are not specific below correctness, could be determined when a mixed specification is employed. Shaping a framework of currency rate yields and examining about variability transference is taken into consideration.

Chuang et al (2007) study mutuality of variability among six markets of East Asia. Foremost, they shape yields within VAR-BEKK structure to develop conventional deviations and afterward employ vector autoregressive model (VAR) to deviations of six markets. Valuation of the VAR model exhibits high level of dependence of stock market conventional deviations. The results imply that market of Japan has largest impact on variability transmission to the others markets and is the least prone to variability incentives from the other markets of East Asia.

Malik and Hammoudeh (2007) study variability transference movement between stock markets of Kuwait, Bahrain, and Saudi Arabia, US stock and world's market of cruel petroleum. They find evidence of essential transference between second momentums. Their results show instability transmission from the global cruel petroleum market to the stock markets of Bahrain, Saudi Arabia and Kuwait, as well as fundamental instability overflow from the stock market of Saudi Arabia to the global cruel petroleum market. They infer that their results are fundamental for creation of correct capital value models, estimation future stock and petroleum value yield variability.

Li and Majerowska (2007) analyze relationships among developed stock exchanges in United States and Frankfurt and developing stock exchanges in Budapest and Warsaw. They employ asymmetric GARCH-BEKK model with four variables. The results exhibit fluctuation overflows from established to developing markets. Nevertheless, since evaluated time varying conventional covariance and deviation exposures imply restricted interplays between markets, developing markets are poorly related to established markets. They infer that external investors can utilize from decline in risk by applying shares into developing markets to the deposit portfolio.

Caporin and McAleer (2008) employ scalar specific case of BEKK multivariate GARCH process employing multivariate prolongation of fluke quotient autoregressive process. Employing theoretic implications disposable into literature about basic multivariate GARCH, the introduction founds substantial constructive and asymptotic features of scalar BEKK process. There are found satisfactory terms about direct DCC GARCH process to be

compliant within scalar BEKK interpretation. Through empirical model, direct DCC GARCH process is compared to indirect DCC GARCH process which is compliant within scalar BEKK interpretation that is developed. The work exhibits that both models are analogical within requirements of implementation parameter valuations and projecting worth at risk rise in uniformly weighted and minimal deviation portfolio, by mean distribution and structure for measuring risk.

Stelzer (2008) finds that every Vec model not introduced within common BEKK frame include matrix like parameter that trace vectorised real mid-specified matrix within determined sub group. Furthermore, common effect from linear algebra is introduced inferring that within extent two models are identical and within extent three models common analytical work out pattern for Vec model holding no BEKK interpretation is specified.

Fengler and Herwartz (2008) employ multivariate GARCH model in order to take up fluctuation grouping and present interrelation of means yields vector. They suppose that covariance of omission allocation pursue interval relied operation relative on informations that are evolved over the operations. They take into consideration framework of currency rates of German mark and British pound estimated versus US dollar. They parallel dynamical characteristics of bivariate process within univariate GARCH determinations where transverse local relationships are neglected. Furthermore, they exemplify the extent of bivariate process with ex ante estimations of bivariate currency level consistency.

Saleem (2009) employs the BEKK-GARCH model offered by Kroner and Engle (1995) to analyze the relationship of Russian stock market to global market and international transference of 1998 Russian monetary crisis. His study exhibits direct relationship among Russian stock market considering the yields and variability. Shortcoming of the relationship implies incorporation strictly in part of Russian stock market within the global market. He finds proof of contagion existence during the crisis.

Ku and Wang (2008) parallel efficiencies of five GARCH models in conditions of VAR back analyzing on amount of estimation declining and mean variance among VAR and produced yield sequences. Contrary the former literature that supposes consistent interrelation quotients, DCC model offered by Engle (2002) is employed to point out time varying conventional interrelations between levels, that is substantial for portfolio risk operation. They analyze indices of stock markets of US, UK and Japan. The results show that DCC model generates minimum estimation decline.

Hafner and Preminger (2009) study asymptotic presumption for multivariate GARCH process within common trend determination offered by Engle, Wooldridge and Bollerslev established like VEC model. The process involves like relevant particular conditions so called BEKK specification and several variants of element GARCH process that is frequently employed. They propose fairly terms for explicit stationarity and geometrical ergogovermentdicity. Dynamic stability of quasi maximum probability valuator is testified under moderate accuracy terms that enable the operation to be incorporated. The presence of sixth direction instants of operation is proposed purposely to get asymptotic regularity.

Wang and Han (2009) employ BEKK and GARCH median worth standardization model in order to study variability interrelations between value of factual assets, funds offer and economics progress, and analyze the influence of different fluctuations on economic development. They find that fluctuation of factual assets value and common trend among factual assets value and funds offer adjustments rapidly, and common shifts among factual assets increase level and economics progress level does not exhibit considerable impact on economiclal development extent's fluctuation. Moreover, the monetary policy keeps various monitoring result on factual assets value within various places. The inference is that fluctuation of factual assets value needs to monitored, yet presently it is not required for central bank to straightforwardly step in factual assets value. To accord properly within acting linkage among primal governance and regional direction within factual assets market is principal implication to enhance the effectiveness of actual assets direction.

Dias and Embrechts (2010) apply open-ended time varying copula model which enable the relative interrelation among currency rates to be time varying and shaped singly from ultimate allocations. Employing Fisher transformation they impose dynamical determination about interrelation employed to US dollar/Yen and US dollar/Euro exchange rates. They find considerably time inconsistent interrelation relied on last yield implementation. Their evidence shows the results procured of variant dynamical landmark models are weaker than results procured of time inconsistent copula models within offered interrelation determination. They inferred that the offered copula within Fischer transformation dynamical process is preponderant to variant models formerly analyzed and supposed that the model has to be regarded like preferential within respect to other models into subsequent papers.

Hafner and Linton (2010) offer multivariate generalization of multiplicative versatility process of Rangel and Engle (2008) that holds non-parametric long-term part and unity multivariate GARCH short-term activity part. They propose different substance established valuation methods for parametric as well s non parametric parts and infer asymptotic characteristics. For parametric component of process, they attain mid-parametric effectiveness edge. Their model is employed to bivariate equity index sequences. They infer that univariate method of Rangle and Engle (2008) emerges to be disrupted within information since the multivariate process is more compliant within information.

Karmakar (2010) analyzes yield and fluctuation overflow results among huge and minor equities into Indian stick market employing everyday indices information. VAR model along with deviation exposure and impulse responsiveness activity study have been applied to disclose volatile and dynamical linkage among huge equities and minor equities. He finds relevant returns overflows from portfolio of market of huge equities to portfolio of minor equities. In order to analyze instability overflow the analysis has employed standard and asymmetric BEKK models. Despite, established on standard BEKK model he studies simplex fluctuation overflows from huge equities portfolio to minor equities portfolio, the revelation is less plausible. The reversible fluctuation overflow among huge equities portfolio and minor equities portfolio that is established on asymmetric BEKK model is more plausible revelation.

Zhao (2010) studies dynamical linkages among factual efficient currency rate and equity value by employing VAR and multivariate GARCH models for period from 1991 to 2009. He finds out unstable long run balance linkage among factual efficient currency rate and equity value. Furthermore, Zhao finds no significant overflows among external stock exchanges. Moreover, he analyses cross variability results among external stock exchanges employing probability ratio statistics. The results exhibit presence of reversible fluctuation overflows results among two markets, implying that former trend-settings within stock exchange have considerable result on future variability within external stock market, and inversely.

Long et al (2011) offer mid-parametric conventional covariance valuator which compounds principal rate parametric conventional covariance valuator within aftermath level non-parametric adjustment valuator into multiplicative run. They validate asymptotic correctness of their semi-parametric conditional covariance valuator, suggest non-parametric analysis for proper determination of parametric conditional covariance methods, and analyze its asymptotic characteristics. They estimate explicit pattern attribute of their analysis and

semi-parametric conditional covariance valuator and parallel the subsequent with parametric conditional covariance valuator, entire non-parametric valuator.

Sadorsky (2012) employs multivariate GARCH model to shape relative interrelations and to study fluctuation overflows among prices of petroleum and prices of shares of pure energy firms and technology firms. He parallels four multivariate GARCH models: dynamical conventional interrelation, invariant conventional interrelation, transverse and BEKK model. He finds that dynamical conventional interrelation model the best matches the data and presents effects exhibiting share prices of pure energy firms correlate less with prices of petroleum than with prices of technology.

CHAPTER 3

3. Stock Exchanges

3.1 Prague Stock Exchange

Prague stock market is supreme and primary arranger of market of shares into Czech Republic. It was closed because of the Second Global War and communistic regime. The stock market was open again in 1993. The market retrieved the functions of Prague items and stock market established in 1871. Exchanging on Prague stock market is directed through permitted stocks dealers. Traders are principally prominent agents and banks. If average depositor determines to deposit on the stock market, he has to meet member of exchange.

Furthermore, most relevant terms within PX grouping are authority trade central Europe and principal stocks support Prague. Power Exchange Central Europe (PXE) is established in 2007 and present new market emplacement for exchanging electricity within Hungary, Slovakia and Czech Republic. Central Securities Depository Prague (CSD Prague) keeps prevalent place into distinct arrangement of stocks exchanges at Czech equity market, holds principal registry of dematerialized stocks published into Czech Republic and distributes stocks international recognizing varieties to trading tools.

Prague Stock Exchange is part of CEE security trade grouping which involve the stock markets of Slovenia, Austria and Hungary. The grouping got on international trade market lake new and powerful performer within September 2009 to stand supreme grouping of trade within Central and Eastern Europe nowdays.

Prague Stock Exchange is part of European stocks trade union and US stocks and trade committee compressed Prague Stock Exchange into register of trade secure for depositors with admitting station of specific offshore stocks market.

3.2. Madrid Stock Exchange

Madrid stock market was established in 1831. The stock exchange is located in plaza de la Lealtad, Madrid.

Over its lasting history, Madrid stock market has performed crucial contribution, running lengthy onward industrialized and economical intervals within subsequent featured with slumps and recessions, yet at all times functioning like reliable indicator of economical activities.

Stock market deals variety of products and represents meeting place for two important parties within free market economy, firms and depositors. Previous upsurge capital plans with emission various securities as firms and depositors, mainstream and sale require yield on the investments.

Stock market commits fundamental role into economy growth since it shifts savings into productive investment and contributes the course of welfare. Stock market like second market provide to depositors opportunity to transform stocks in cash. One of the fundamental characteristics of the market is liquidity.

It was featured like productive and stable source of progress by royality decision which enable establishment of Madrid stock market. That is what the stock exchange has kept to be over the lengthy track, when house composition was particular meeting place employed by investors and firms to perform essential function in the progress of Spain through past period, since new technology have stifled the mainstream function on market place. Nevertheless, stock exchange holds to be fundamental player within a function like source of funding to firms.

3.3. New York Stock Exchange

New York Stock Exchange (NYSE) is major world financial market leader and supplier of original market technology. It is the biggest stock market by market capitalization. NYSE is directed by NYSE Euronext which was found by NYSE union within purely electronically stock market Euronext. NYSE secures assets for purchasers and dealers of shares within firms registered for open market. At marketplace, NYSE deals within constant sale extent where dealers may pursue shares purchase on behalf of depositors. The traders group beside relevant place where expert agent who work for NYSE member company, operates like auctioneer into open call competitive bidding market center to carry purchasers and dealers altogether and to handle the present competitive bidding. They periodically support dealers undertaking their proper capital and like concern of run spread news to the aggregate which contribute to carry purchasers and dealers altogether. The competitive bidding operation shifted into automation by using wireless computers in 1995. The framework facilitates dealers to get and perform order in electronic form through wireless broadcasting. From 2007, NYSE shares could be carried through electronically hybrid market. Buyers now may deliver orders for direct electronic commitment, or direct orders to

the marketplace within competitive bidding market. NYSE operates with controllers as US Securities and Exchange Commission and Commodity Futures Trading Commission to synchronize risk operation standards within electronically market over usage of mechanisms as volume separators and liquidity provisions items.

CHAPTER 4

4. Methodoogy

4.1 Modeling Volatility

Studying the stock exchange activities and insecurity, agents may understand that sometimes yields vary from average by larger extent. Ordinarily, intervals with small deviations incline to be tracked by intervals with little uncertainty, as well as intervals with much uncertainty strive to be tracked by intervals with large variability of yields. It indicates that uncertainty could be exploited like an indicator of uncertainty in future. Variability grouping is process in which slight variations strive to be tracked by slight variations and huge variations incline to be tracked by huge variations.

Average returning variability is further stylized reality for yields interval sequences of stock exchanges. It indicates standard variability rank which variability strives towards.

Furthermore, large queues into partition of yields is other distinctive hallmark about the financial interval sequences. This is fairly ordinary for the partition of yields to be impaired and paralleled with large queues to standard partition. Those partitions, which register intent information towards average as well as have larger variability than standard partition are interpreted like leptokurtic.

Moreover, plenty experiental researches imply that plenty more variability exists into assets yields which may not be warranted within deviations of relevant economical variables. Typically, huge fluctuations into yields cannot be elucidated by coming of market's news.

Furthermore, equity markets are realized to respond variously to positive and negative news, showing asymmetrical influence on variability. The inclination of "bad" news to generate larger instability into next intervals versus positive news influence is interpreted as leverage result.

Instability grouping, interpreted like an error condition asserting time inconsistent heteroscedasticity, the leptokurtic sharing of the stock market yields, and the plausibility of presence of dynamics results as well as partition of stock market yields sustain certain limitations regarding the employment of samples within evaluating the fluctuation of stock exchanges. Under this sort of conditions, linear patterns cannot interpret sufficient the

features of financial interval sequences. ARCH and GARCH pattern forms are employed for shaping sequences which do not meet premise of homoscedasticity. Such types of patterns enable deviation to be subject of its own history. ARCH specification employs projected rates about primeval variability within aim to evaluate deviation. Broadly employed GARCH model specifies that prime valuation of the deviation is standard of long-term mean deviation, the deviation projected upon ongoing interval as well as the news within running time, taken of foremost latest quadrate balance (Engle 2001).

4.2. Univariate GARCH Model

Versatility could be interpreted like count of instability or danger for variety of shifts into price of stock. Under versatility of particular facilities signify that the one keeps small level of amendment in value through particular interval. On the other hand large versatility imply that value of means may shift drastically through short-term time frame. The one is needful to emphasize that definition of versatility asserts the two real and demerit shifts within value of means.

Because versatility may substantially affect ready money inflows and outflows, it is necessity for trading brokers to evaluate versatility. Originally brokers employed stock variance like criterion, though its weakness is that it cannot take up variations through period. Straightforward admittance is to employ primeval versatility determined like primeval versatility merely embraces computing variation of yields in common form to certain primeval interval, and it there result in versatility prediction about subsequent intervals (Brooks 2008). Weakness of that admittance is infirmity to correctly determine proper time through which valuations for versatility would be done.

Another form of valuation versatility is progressively rated shifting medium that Brooks (2008) determines like elementary spread of primeval medium versatility rate that enables latter perceptions to get more powerful influence to predict versatility than former information items. Furthermore the process is similarly featured with restriction of not converging into implicit deviation by enhancement of projection prospect.

Engle offered ARCH (Autoregressive Conditional Heteroscedasticity) process like response to all noticed weaknesses. Regarding revelation of ARCH process Engle said that he

was searching model which can estimate justifiability of Friedman's premise that inflation's incalculability was fundamental reason of working periods. Friedman assumed that instability regarding expenses and values which will discourage vendors to invest and will run to slump. Also he did not consider inflation rate like an issue. It can soley be adequate in the case of modification in instability through time which was Engle's objective. That is known as heteroscedacity (Engle 2004).

ARCH process is defined like:

$$y_t = \mu + \rho y_{t-1+} + \varepsilon_t$$

ε_t indicates trend-settings within standard null and time inconsistent conventional deviation h_t^2

$$\varepsilon_t \sim N(0, h_t^2)$$

ARCH specification is purely determined by specifying conventional deviation standardization:

$$ht^2 = \omega + \alpha\varepsilon^2_{t-1}$$

Because conventional deviation (ht^2) has every time to be equal or greater than null quotients α and ω have to be equal or greater than null ($\alpha \geq 0$ and $\omega \geq 0$).

Yet, ARCH models are subject of restrictions. Brooks (2008) determined the general restrictions of ARCH model like below:

- query for determination of variety of lags of quadratic reliques in patterns;
- reality that variety of lags of quadratic reliques needful to capture interdependence within conventional deviation can be huge;
- positive or zero restriction can be interrupted.

Generalized ARCH specification was established in 1986 by Tim Bollerslev as variant of ARCH. GARCH (General Autoregressive Conditional Heteroscedasticity) enables modifiable lag frame and evaluates deviation like medium of a few various deviation estimations. The first one is invariant deviation which match long process standard. Second one is estimation which was done within latest interval. Third is update which was inaccessible at time at

which the latest estimation was done. It can be seen like estimation of deviation found on data of one time interval. Average of these estimations specifies the speed of vary of data and the speed of returning to long process average (Engle 2004). Bollerslev in 1986 recorded that resumption of ARCH model to GARCH model sustains hugely similarity to expansion of common period sequences AR method to standard ARMA method.

Phrase conventional heteroscedasticity acts to deviation which varies over periods established at former sample, either which versatility is varying, conventional upon extent of variability in former interval.

About determining GARCH process we suppose that a variable pursues procedure:

$$y_t = \mu + \rho y_{t-1+} + \varepsilon_t$$

also supposing $\rho < 1$, which implies that operation upward is consistent

ε_t in former equalization indicates stochastic movement under premise that I_t is data sept of whole data over period t, GARCH model is specified as:

$$\varepsilon_t \mid I_{t-1} \sim N(0,h_t)$$

$$h_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{i=1}^{q} \beta_i h_{t-1}^2$$

$p \geq 0, q > 0$
$\omega > 0, \alpha_i \geq 0, i = 1,\ldots,q$
$\beta_i \geq 0, i = 1,\ldots,p.$

Likewise as into ARCH process, with a view to positive or zero restriction not to be interrupted, the premises $\omega > 0$, $\alpha_i \geq 0$, and $\beta_i \geq 0$ are required.

Because most employed determination of this process in fact is GARCH (1,1) that in principle evaluates conventional deviation soley within employing prime delays of former conventional deviation and quadrate omission condition, processes keep further shape:

$$h_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}^2$$

Within GARCH standardization valuated upward, prime indicator about following interval deviation is rated mean of:

- Deviation in long time frame (ω)
- Ongoing interval present deviation (α)
- Deviation anticipated for running interval (β)

Earlier vaulting shocks substantially impact present conventional versatility that explicates existence of versatility aggregating within financial interval sequences. Versatility grouping like noticed earlier is perception that huge amendments strive to be trailed by huge amendments as well as minor amendments incline to be traced by minor amendments. (Mandelbrot 1963)

Characteristics of GARCH model may feature unwished when conventional deviation quotients valuations flat out to meet consistency of deviation. Because implicit deviation ε_t is invariant and specified as:

$$\text{var}(\varepsilon_t) = \frac{\omega}{1-(\alpha+\beta)}$$

offence of premise $\alpha + \beta < 1$ can pursue to non-consistency of deviation, whereas $\alpha + \beta = 1$ implies item base of deviation. Wald test can be employed to test consistency of deviation.

Strength of GARCH model beside ARCH model could be sum up in reality that GARCH model is rather tight and escape further setting. Furthermore that is little supposedly that the process would violate positive and zero restrictions (likelihood that by involving parameters in conventional deviation equalization that is presumably any of these parameters to have positive or zero calculated price). Brooks (2008).

GARCH process as well as conventional deviation equalization could be asserted like ARMA (Autoregressive Moving Average) process as Enders (2003) and Brooks (2008) proposed. Taking into consideration $h_t^2 = \varepsilon_t^2 - e_t$ with replacing and ordering conventional deviation equalization we derive:

$$\varepsilon_t^2 = \omega + (\alpha + \beta)\varepsilon_{t-1}^2 - \beta e_{t-1} + e_t$$

This equation indicates ARMA (1,1) model about quadrate deviations.

GARCH process gets variety of determinations about holding few particular impacts typical for interval sequences. Substantial constraint of primal GARCH specification is premise which assumes symmetrical respond of versatility to real shocks. GJR development offered by Glosten et al. (1993) evaluates existence of leverage result into particular interval sequences with involving further term about potential asymmetries. The result features asymmetrical impact of news on versatility or inclination of non positive news to evoke larger variability into further time frame equated to positive news impact. TARCH (1,1) model is determined:

$$h_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}^2 + \gamma I_{t-1}\varepsilon_{t-1}^2$$

$I_{t-1}=1$, in the event of $\varepsilon_{t-1} < 0$ and 0 or

In an event of $\gamma = 0$, asymmetrical impact exists, GJR=GARCH

OLS specification could not be applied for GARCH valuation, because OLS marginalizes RSS which do not relies on fundamentals within deviation equalization, but relies soley on fundamentals within median equalization. Owing to mention above OLS engineering ought to be replaced by ultimate probability technics. Probability distribution under normality presumption of interruptions can be expressed in the following way:

$$L = -\frac{T}{2}\log(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\log(h_t^2) - \frac{1}{2}\sum_{t=1}^{t}(y_t - \mu - \rho y_{t-1})^2/h_t^2$$

In this equation T indicates amount of perceptions.

Substantially, process runs through determining fundamentals within fundamental scope which maximizes probability distribution.

Principal employment of GARCH specification is inclination to be applied for prediction variability of sequences through periods. Fundamentally, GARCH specification is employed to depict shifts within potential deviation of omission condition, though as it could be verified:

$$\text{var}\,(y_t \mid y_{t-1}, y_{t-1}, \ldots) = \text{var}\,(u_t \mid u_{t-1}, u_{t-2}, \ldots)$$

shapping potential deviation of u, would generate projection of y_t.

4.3. Multivariate GARCH Model

Argumented univariate GARCH process evaluates unique variable versatility features and versatility progress over periods. That characteristic of univariate GARCH specification could be upgraded with determining particular multivariate GARCH determination. Whereas univariate GARCH model analyzes deviation of one variable, multivariate GARCH model analyzes interplay among few variables with evaluating progress of covariance over periods. Multivariate GARCH specification could be employed within few particular conditions, however most worthwhile usage is about analyzing relationships among variabilities, covariances and deviations among various markets.

Because of aim of the analysis we use multivariate GARCH model to analyze shifts within variability of Czech stock exchange and Spanish stock exchange. With employing that sort of GARCH model we would attempt to disclose fluctuations relay as well as overflows among stock markets. Furthermore, multivariate GARCH specifications evaluate impact of versatility stir among stock exchanges. Moreover, multivariate GARCH specification generates potential interrelation sequences that approaches shifts in versatility of various markets over intervals. We would employ bivariate GARCH model.

Multivariate GARCH about vector stochastic movement of extent N x 1 was developed by Bauwens et al. (2006) and determined like:

$$y_t = \mu_t + \varepsilon_t$$

$$\varepsilon_t = H_t^{\frac{1}{2}} v_t$$

v_t is N x 1 random vector meeting $E(v_t) = 0$ and $Var(v_t) = I_N$,
I_N is equality shape.

Conventional deviation shape y_t is determined like:

$$Var(y_t|I_{t-1}) = Var_{t-1}(y_t) = Var_{t-1}(\varepsilon_t)$$

$$= H_t^{\frac{1}{2}} \mathrm{Var}_{t-1}(v_t)(H_t^{\frac{1}{2}})^T$$

$$= H_t$$

is N x N real determined shape, H_t is conventional deviation shape y_t

Conventional covariance shape is asserted by subsequent standardization by Kroner and Engle (1995):

$$H_t = \Omega^T \Omega + \sum_{k=1}^{K} A_k^T \varepsilon_{t-1} \varepsilon_{t-1}^T A_k + \sum_{k=1}^{K} B_k^T H_{t-1} B_k$$

The model is eminent like BEKK-GARCH and we are going to employ this model for the aim of the analysis. Total range K specifies entire procedure. We suppose K to be equivalent to 1, delays p and q to be equivalent to 1. Furthermore we suppose framework N of 2 variables for the bivariate case.

We assume Ω, A and B to be 2 x 2 fundamental's matrices. Ω indicates instep triangular matrix. Determination of BEKK process can be represent in following matrix designation frame:

$$\begin{bmatrix} h_{11t} & h_{12t} \\ h_{12t} & h_{22t} \end{bmatrix} = \begin{bmatrix} \omega_{11} & 0 \\ \omega_{12} & \omega_{22} \end{bmatrix} \begin{bmatrix} \omega_{11} & \omega_{12} \\ 0 & \omega_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^T \begin{bmatrix} \varepsilon_{1t-1}^2 & \varepsilon_{1t-1}\varepsilon_{2t-1} \\ \varepsilon_{2t-1}\varepsilon_{1t-1} & \varepsilon_{2t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^T \begin{bmatrix} h_{11t-1} & h_{12t-1} \\ h_{12t-1} & h_{22t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

Widen conventional deviation and covariance in bivariate BEKK-GARCH can be featured like:

$$h_{11t} = \omega_{11}^2 + a_{11}^2 \varepsilon_{1t-1}^2 + 2a_{11}a_{21}\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{21}^2 \varepsilon_{2t-1}^2 + b_{11}^2 h_{11t-1} + 2b_{11}b_{21}h_{12t-1} + b_{21}^2 h_{22t-1}$$

$$h_{22t} = (\omega_{12}^2 + \omega_{22}^2) + a_{12}^2 \varepsilon_{1t-1}^2 + 2a_{12}a_{22}\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{22}^2 \varepsilon_{2t-1}^2 + b_{12}^2 h_{11t-1} + + 2b_{12}b_{22}h_{21t-1} + b_{22}^2 h_{22t-1}$$

$$h_{12t} = (\omega_{11}\omega_{12}) + a_{11}a_{12}\varepsilon^2_{1t-1} + (a_{11}a_{22} + a_{12}a_{21})\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{21}a_{22}\varepsilon^2_{2t-1} +$$
$$+ b_{11}b_{12}h_{11t-1} + (b_{11}b_{22} + b_{12}b_{21})h_{12t-1} + b_{21}b_{22}h_{22t-1}$$

Variable h_{12t} indicates conventional covariance, whereas h_{11t} and h_{22t} indicate conventional deviations. Requirement about covariance steady like amount B+A matrices which is lower than 1 within quotient is determined by Bauwens et al. (2006).

We will evaluate 11 fundamentals within BEKK(1,1,1)-GARCH model by using formula N(5N+1), because N=2.

4.4. Empirical Methodology

Data required to perform the evaluations is provided by Reuters 3000 Xtra Terminal. Analyzed interval covers roughly 10 years interval commencing in January 2002 and closing in March 2012. In our study we take into consideration two indices PX (Prague Stock Market) and IGBM (Spanish Stock Market) on everyday basis. Furthermore, we explore NASDAQ100 (US Stock Market) like particular landmark in order to analyze if there is impact of the crisis which began in US on stock markets of Czech Republic and Spain.

Purposely to do effective study on versatility we need to alter indices to returns. We employ the consequent formula in order to change indices to returns:

$$R_t = \log(P_t) - \log(P_{t-1})$$

P_t represents everyday ending index worth in period t, P_{t-1} represents ending worth in prior day, log is actual logarithm and R_t indicates level yields interval sequences.

At the commencement of our study of yields interval sequences we introduce distinct statistics. Descriptive statistics presents principal characteristics of three interval sequences concern of the study. It outlines the features of return time series by mean, minimum, maximum and standard deviation. Mean shows median worth, minimum exhibits minimal perception of population, maximum shows ultimate perception of population while standard deviation indicates the scope of deviation from the median worth. Jarque-Bera test sums up the features of return time series by the test statistics, p-value, skewness and kurtosis.

Skewness represents asymmetry of likelihood allotment of yields interval sequences, while kurtosis exhibits the form of likelihood allotment. Jarque-Bera test measures the distance between distribution and standard one.

Furthermore we perform Augmented Dickey Fuller (ADF) test to analyze for stationarity. ADF test is unity radix test which assumes that dismissal of zero premise of unity radix signifies that analyzed interval sequences are steady. Non-dismissal of zero premise infers particular interval sequences like non-steady. The necessity of analyzing stationarity is developed from danger of excess decline costs from non-steady interval sequences.

We employ BEKK-GARCH model because our goal is to analyze interdependence among Czech and Spanish stock market. Prior evaluating bivariate BEKK-GARCH, we amend interval sequences and employ soley days with registered index amounts about the pair of NASDAQ 100 and PX index or IGBM index. We also perform Jarque-Bera test, Portmanteau and Multivariate ARCH-LM test. We estimate three matrices Ω, A and B.

Matrix Ω is determined like:

$$\begin{bmatrix} \omega_{11} & \omega_{12} \\ 0 & \omega_{22} \end{bmatrix}$$

Matrix A is determined like:

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

Matrix B is determined like:

$$\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

4.5. Hypotheses

We want to find out in which way the financial crisis that originated in US affects the stock markets of Czech Republic and Spain.

We determine our hypotheses like:

- The stock market of the Czech Republic is less affected by the Financial Crisis than

the stock market of Spain.

- Impact of the crisis on the stock markets is economically and statistically significant.
- Stock markets of Czech Republic and Spain are correlated.

CHAPTER 5

5. Empiric Part

5.1. Initial Analysis

The charts down present the movement of indicators and yields time sequences over the studied interval. In the first place, plot of NASDAQ100 is featured like particular landmark of European stock shifts. Essential distinction of NASDAQ100's movement is significant crash raised from worldwide financial crisis. Lowermost spots are noticed in the last quarter of 2008 and first quarter of 2009, and afterwards the index has increased rapidly. The recovery from the slump was quick.

Figure 1: NASDAQ levels, January 2002-January 2012

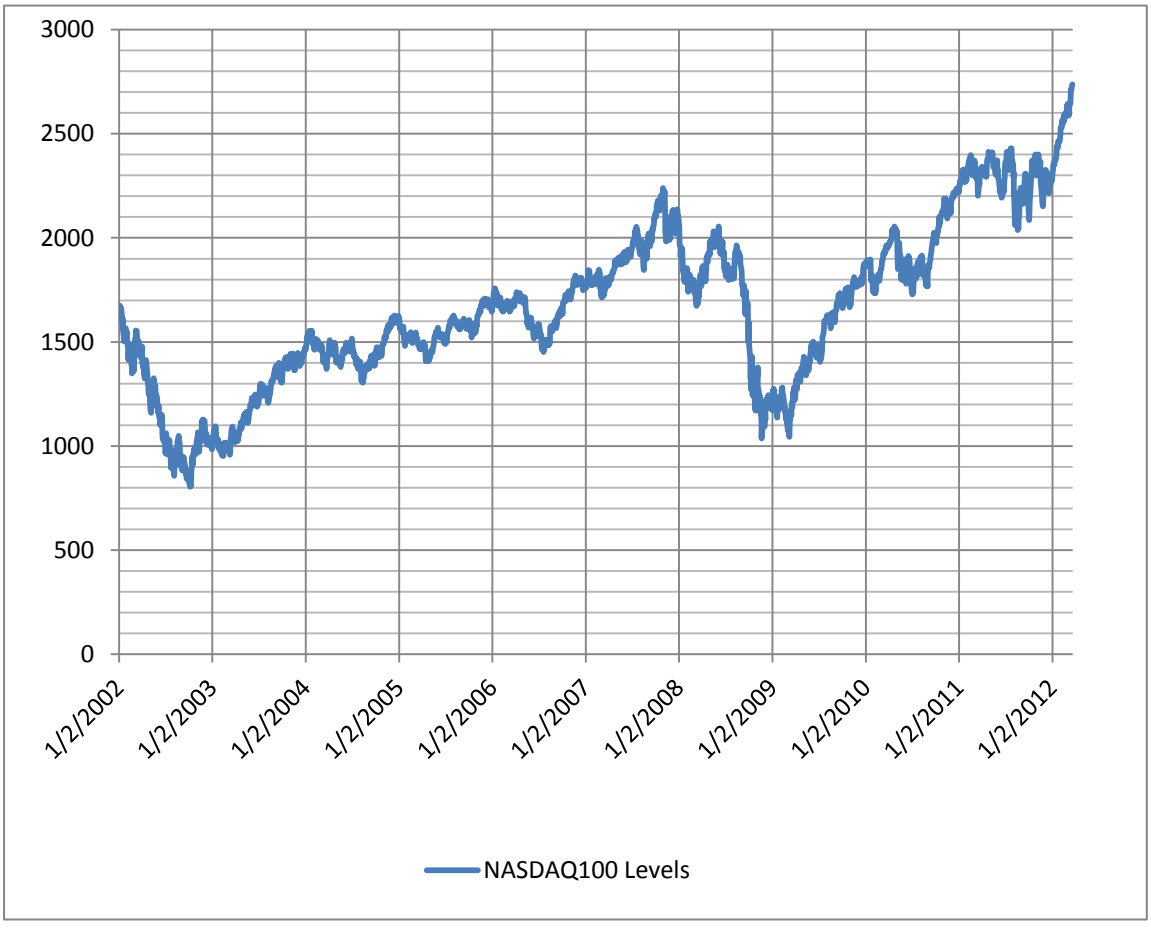
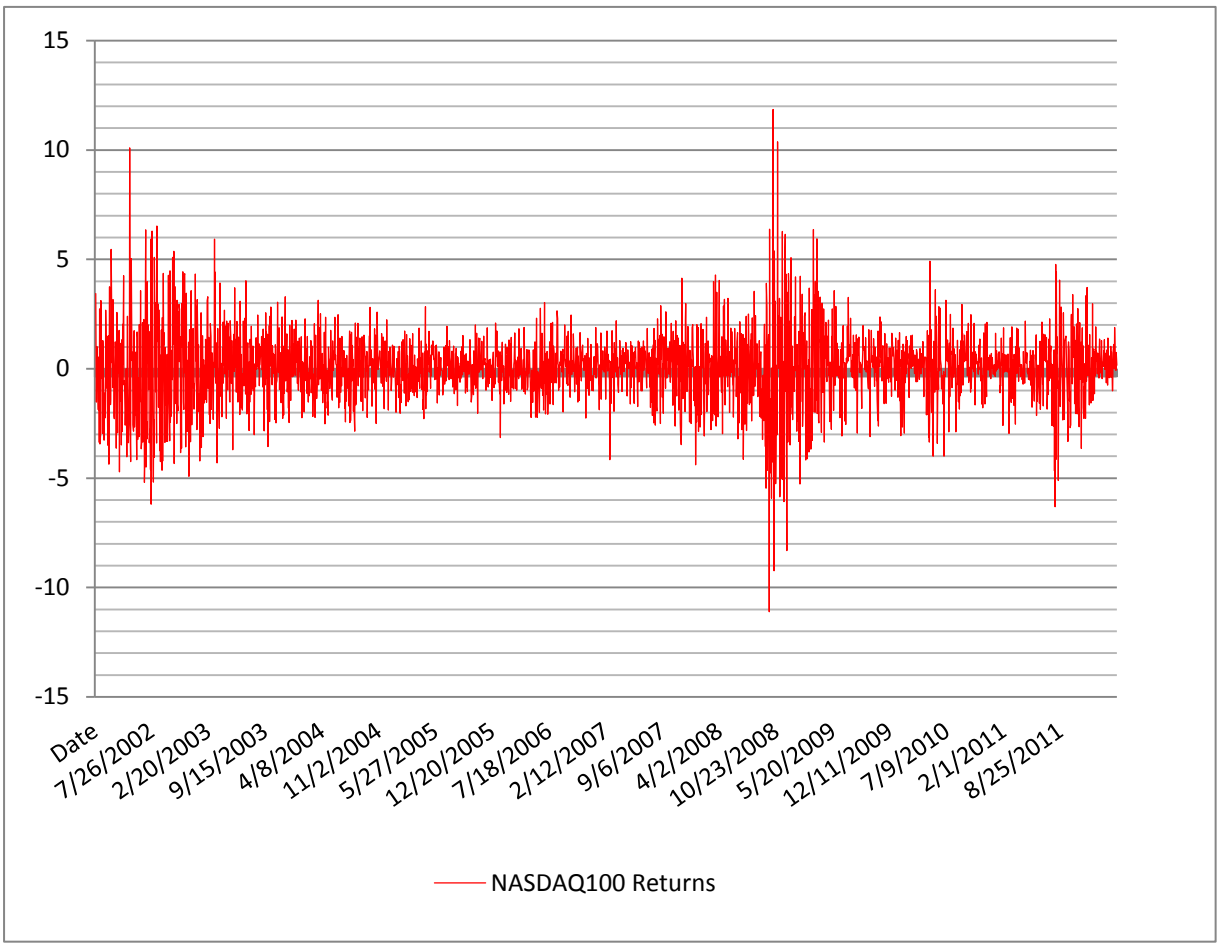
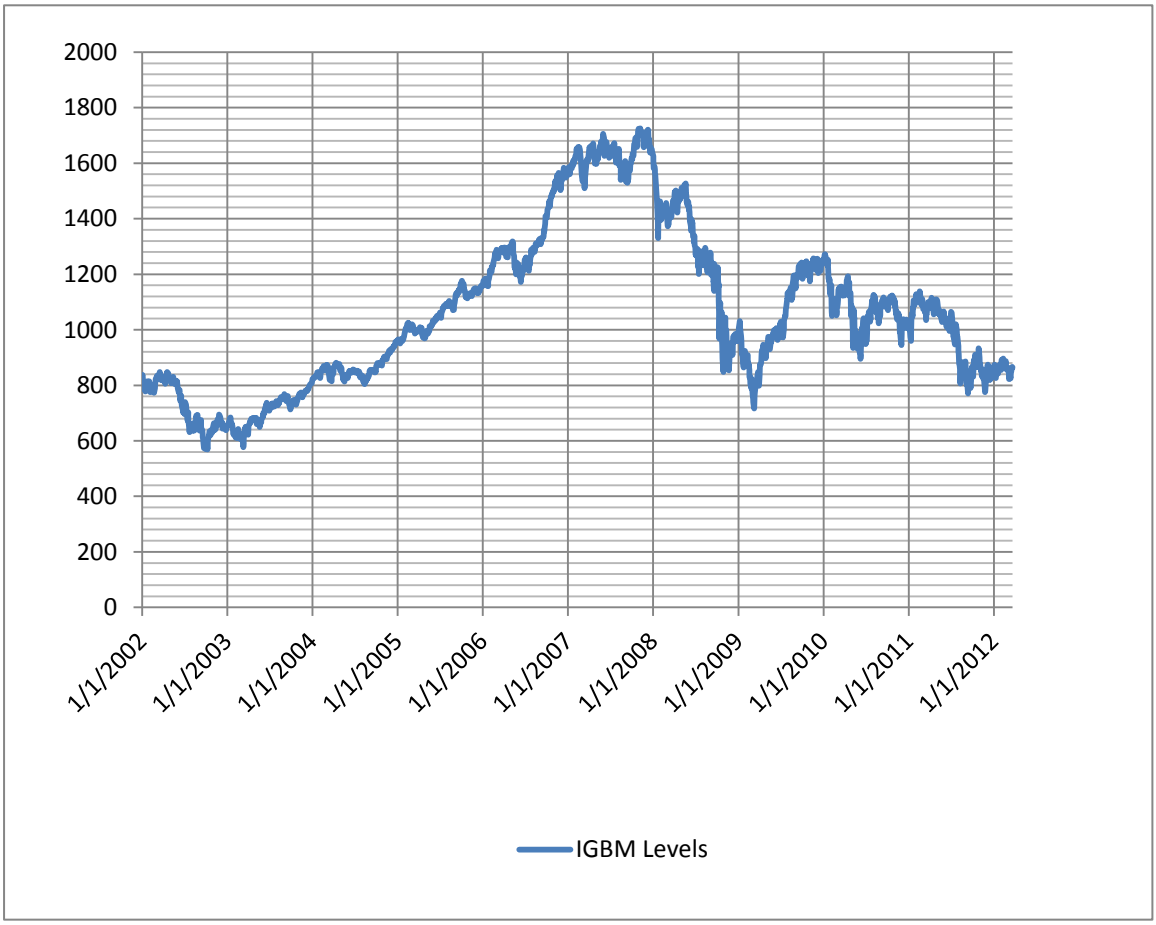


Figure 2: NASDAQ returns, January 2002-January 2012



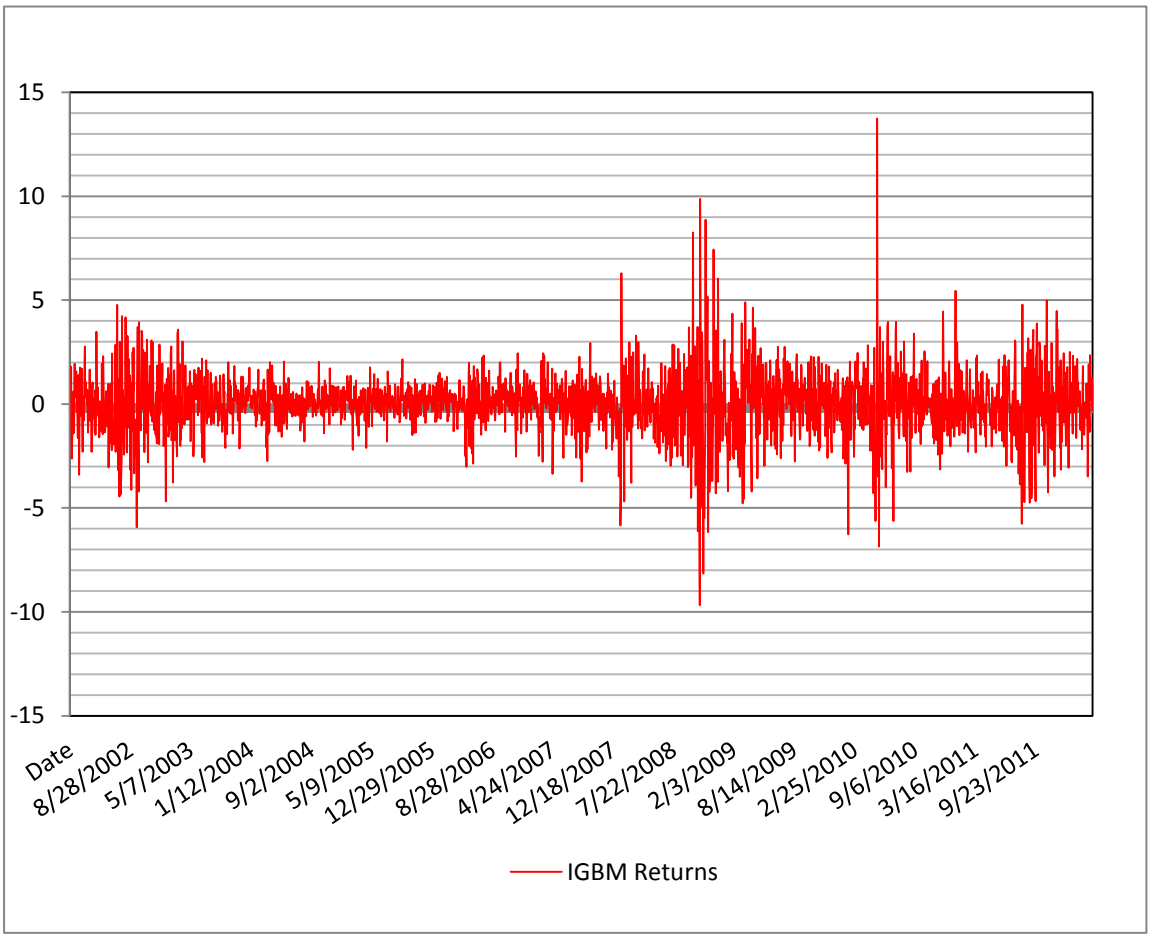
The volatility of NASDAQ100 is highest during final quarter of 2008 and first quarter of 2009. The interval of crash and reestablishment is the major variability period in yields time sequences. Fairly greater variability with rapid recovery subsequent to crisis is featured for NASDAQ100.

Figure 3: IGBM levels, January 2002-January 2012



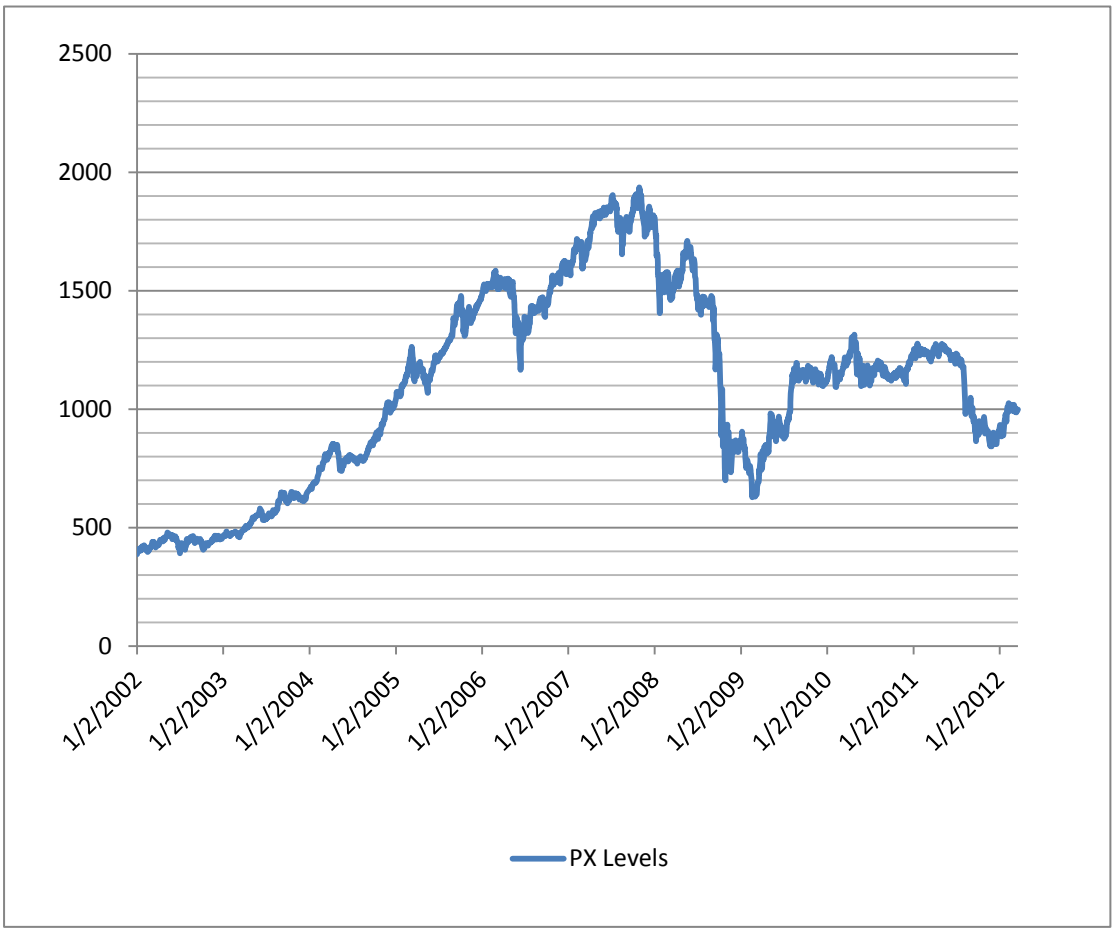
Spanish stock exchange (IGBM) also crashed as a consequence of worldwide financial crisis. The lowest points are noticed in the first quarter of 2009. Afterwards in the same year the index slightly increased. Since that period IGBM index has declined.

Figure 4: IGBM returns, January 2002-January 2012



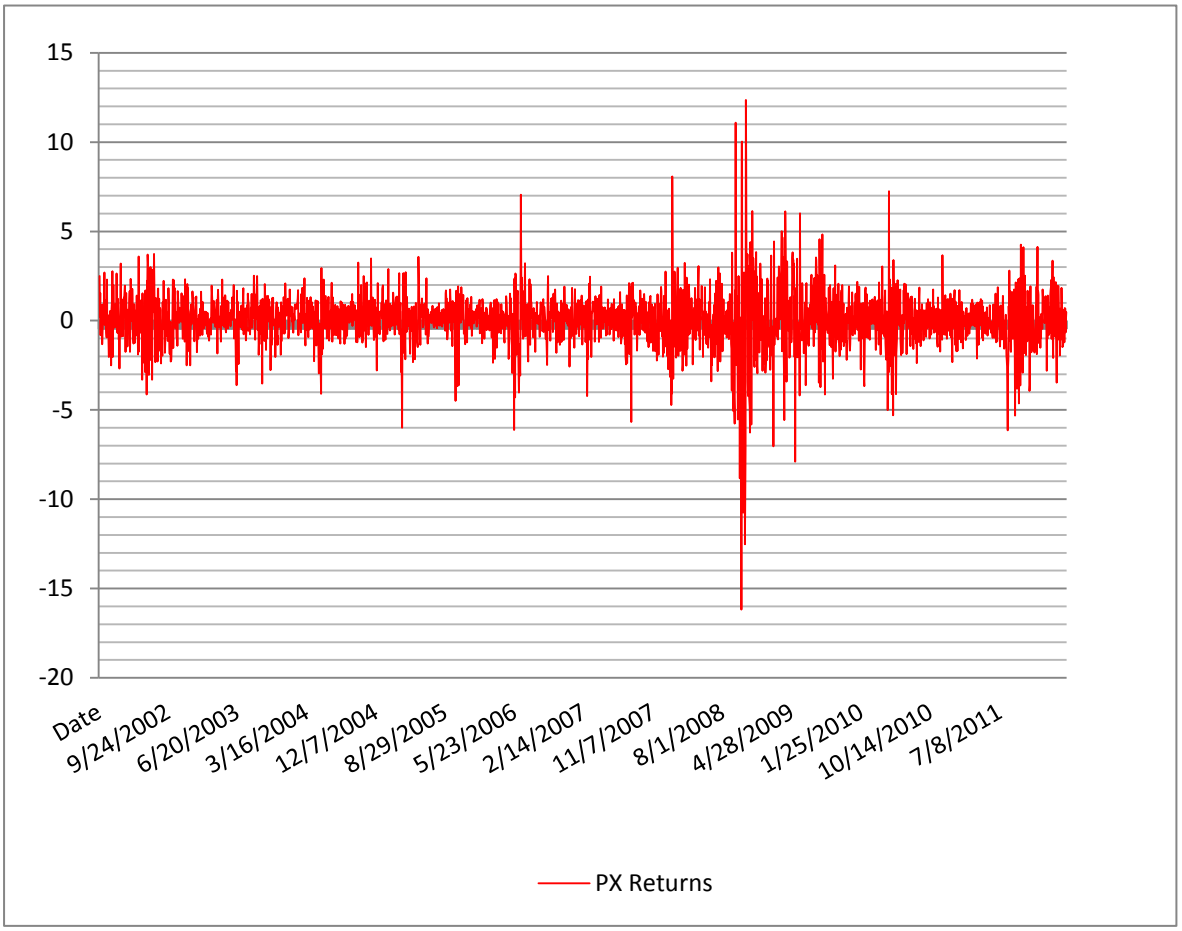
IGBM is featured by high volatility during the global financial crisis and in the years afterwards. The volatility was highest in the first quarter of 2009.

Figure 5: PX levels, January 2002-January 2012



Prague stock exchange (PX) index similarly had slump raised by worldwide financial crisis. Lowest spots are noticed in the first quarter from 2009. The same year the PX index increased. Afterwards the index was stagnant for two years. In the last two quarters of 2011 the index slightly declined.

Figure 6: PX returns, January 2002-January 2012



PX index is featured by large variability and slow movement of recuperation. The index notices the most variability interval into the final quarter of 2008 under impact of Lehman Brothers's crash.

Table 1: Descriptive Statistics

variable	mean	min	max	standard deviation
NASDAQ	8.68943e-05	-1.27284e-01	1.01370e-01	7.78257e-03
IGBM	5.01516e-06	-4.20393e-02	5.96597e-02	6.24438e-03
PX	1.54945e-04	-7.02926e-02	5.36964e-02	6.71596e-03

Spanish Stock Exchange shows higher mean return per day 5.01516e-06 % for the interval from January 2002 to January 2012 than Prague Stock Exchange 1.54945e-04 % considering mean. Also Spanish Stock Exchange exhibits higher maximum return per day 5.96597e-0 % than Prague Stock Exchange 5.36964e-02 %. Prague Stock Exchange -7.02926e-02 shows lower min return per day than Spanish Stock Exchange -4.20393e-02. Standard deviation exhibits that Prague Stock Exchange 6.71596e-03 is more versatile than Spanish Stock Exchange 6.24438e-03.

Table 2: Jarque-Bera test

variable	Teststat	p-value	skewness	kurtosis
NASDAQ	180032.3994	0.0000	-0.7766	43.3341
IGBM	7240.4516	0.0000	0.1509	11.0891
PX	20280.6474	0.0000	-0.5725	16.4990

Kurtosis and skewness are criterions about how much distribution is near to standard one. Interval sequences of PX and IGBM indices show greater worth of kurtosis than 3 which is worth of standard allotment. Spanish Stock Exchange shows higher skewness 0.1509 than Prague Stock Exchange -0.5725. PX index exhibits higher kurtosis then IGBM index. PX index exhibits higher kutosis 16.4990 than IGBM index 11.0891. Jarque-Bera test acknowledges the kurtosis and skewness results. It is a goodness of fit criterion of deviation of standard allotment. Large values of Jarque-Bera test along with p-value imply that zero presumption of normality is refused for all yields interval sequences. Jarque-Bera test confirms that allotment of yields is leptokurtic, which is particularity specific for financial yields interval sequences.

Furthermore ADF test verifies that all yields interval sequences are stationary. ADF test holds zero presumption of unity root in event of no intercept, intercept and intercept and time trend test. The unity root presumption is refused at 1% importance level.

Table 3: ADF Test

variable	no intercept	p-value	intercept	p-value	intercept and time trend	p-value
NASDAQ	-32.1601	0.0000	-32.1628	0.0000	-32.1879	0.0000
IGBM	-31.8941	0.0000	-31.8882	0.0000	-31.9058	0.0000
PX	-31.6957	0.0000	-31.7200	0.0000	-31.8084	0.0000

5.2. Multivariate GARCH Valuation

Bivariate BEKK GARCH determination employed for multivariate GARCH valuation encourage to find out conventional variability among returns of Czech and Spanish stock markets and NASDAQ100 index. Estimated multivariate GARCH features for every model among Czech and Spanish stock exchange returns and returns of NASDAQ100 index are presented into consequent tables. Into every table index one indicates the returns series of IGBM or PX indices and index two indicates the NASDAQ100 returns. The $h_{11,t}$ represents conventional deviation of IGBM and PX returns, $h_{22,t}$ represents conventional deviation of NASDAQ100 returns and $h_{12,t}$ exhibits conventional covariance among IGBM and PX returns sequences and NASDAQ100 returns sequences. The symbol ε represents the impact of the omission on conventional variability. The quotients in bold are functions of statistically fundamental quotients. The quotients which are not in bold are estimated by multiplication of the quotients which are not significant statistically. The overall results of multivariate GARCH valuation as well as tests for residuals are presented in the following table.

Table 4: BEKK-GARCH models valuations for IGBM and PX returns, and NASDAQ100 returns

	Ω		A		B						
IGBM-NASDAQ100	0.0006**	0.0005	0.2423**	-0.1634	0.9656***	0.0470	Log Likelihood	19835.5	JARQUE-BERA		
	(11.6528)	(1.9653)	(20.2339)	(-6.5927)	(260.8745)	(5.9121)	PORTMANTEAU		vari	xi_1	xi_2
	(6.24156)	*(1.8875)*	*(7.8391)*	*(-1.2394)*	*(133.5353)*	*(1.0461)*	(H0:Rh=(r1,...,rh)=0)				
							tested order:	16	teststat	425.2575	954835.7132
							adjusted test	164.619			
							p-value:	0.000	P-	0.000	0.000
	0.0000	1.0017	0.0283	0.3404**	-0.0114	0.9284***	Multivariate ARCH-	k=16			
	(0.0000)	(14.0842)	(2.1894)	(16.8946)	(-2.7323)	(238.130)	test statistic:	50.9256	skew	-0.2578	-3.1357
	(0.0000)	*(1.5521)*	*(1.5480)*	*(4.2841)*	*(-1.4138)*	*(22.4497)*	p-value(χ^2):	0.000	kurtos	4.8928	95.7454
PX-NASDAQ100	Ω		A		B		Log Likelihood	19587.9	JARQUE-		
	0.0010	0.0004	0.2914**	-0.0530	0.9404**	0.0166	PORTMANTEAU		variab	xi_1	xi_2
	(14.0836)	(2.0635)	(21.8042)	(- 2.2506)	(168.3067)	(1.6632)	(H0:Rh=(r1,...,rh)=0)				
	(0.8687)	*(0.1554)*	*(5.1205)*	*(-1.1631)*	*(17.7574)*	*(0.4550)*	tested order:	16	teststat	437.3406	666734.8624
							adjusted test	214.163			
							p-value:	0.0000	p-	0.000	0.000
	0.0000	0.0015	0.0385	0.3796	-0.0155	0.9250**	Multivariate ARCH-	k=16			
	(0.0000)	(16.912 9)	(3.3666)	(22.2081)	(-5.2591)	(207.768 3)	test statistic:	25.3645	skew	-0.3313	-2.4742
	(0.0000)	*(0.5713)*	*(0.2210)*	*(2.0082)*	*(-0.1486)*	*(7.1419)*	p-value(χ^2):	0.9071	kurtos	4.8758	80.5198

Notes: The denotation ***, ** determine significance at 1% and 5% respectively; the coefficients are evaluated employing QML Quasi Maximum Likelihood); the italic numbers within brackets are t-values exact; the numbers into brackets are t-values normal; the dataset involves daily observations from 2.1.2002 to 20.03.2012; Creator's computations in JMulTi based on Reuters 3000 Xtra Terminal data.

The evaluated results for multivariate GARCH model for IGBM and NASDAQ100 exhibit significant impact to Spanish stock exchange returns variability by the past shocks and past conditional variability. The effect of its own conditional variability is grater for IGBM_R than for NASDAQ100_R (0.932 versus 0.862). NASDAQ100_R is more affected by its own past shocks than IGBM_R (0.116 versus 0.059). The table below exhibits that NASDAQ100 conditional variance is directly influenced only by its own past shock in variability and its own past conditional variance.

Spanish stock market shows statistically significant, but relatively low, nearly irrelevant, variability spillover from US stock exchange.

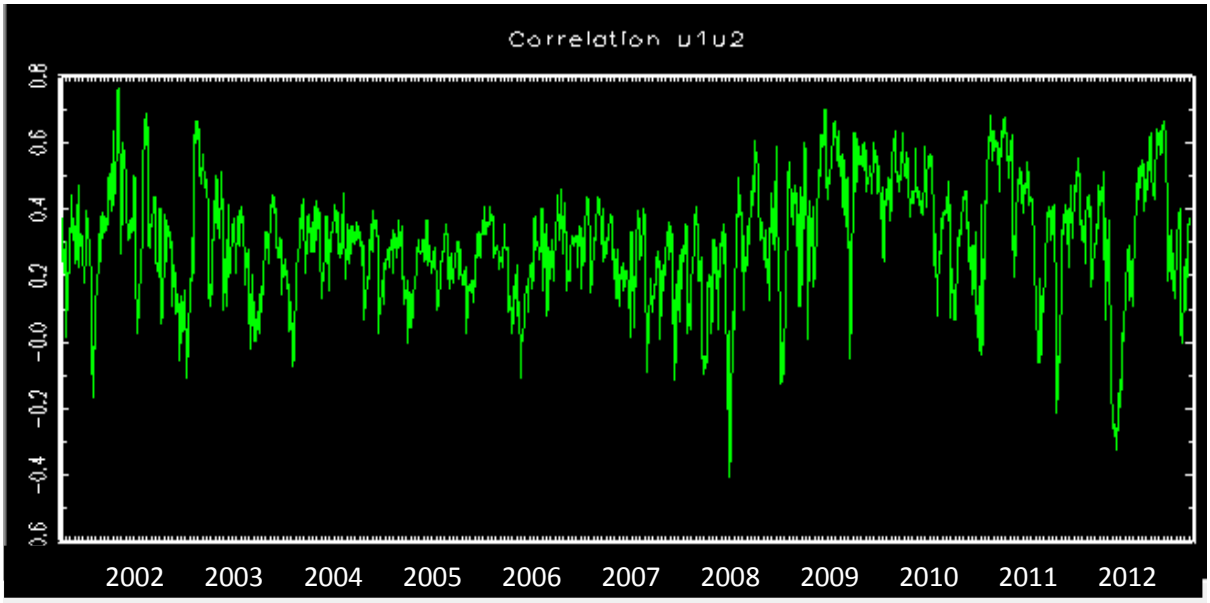
Table 5: Bivariate GARCH coefficients valuations for IGBM and NASDAQ100 returns

IGBM	constant term	ε_1^{2}, t-1	$\varepsilon_1\varepsilon_2$, t-1	ε_2^{2}, t-1	$h_{11, t-1}$	$h_{12, t-1}$	$h_{22, t-1}$
$h_{11,t}$	**0.00000036**	**0.05871**	0.01371	0.00080	**0.93238**	-0.02202	**0.00013**
$h_{22,t}$	1.00340	0.026700	-0.11124	**0.11587**	0.00221	0.08727	**0.86193**
$h_{12,t}$	0.00050	-0.03959	0.07785	0.00963	0.04538	0.89593	-0.01058

Notes: the pattern involves 2653 observations from 02.01.2002 to 20.03.2012; Creator's computations in JMulTi based on Reuters 3000 Xtra Terminal data

Conditional correlation coefficient among Spanish and US stock exchange returns is hugely varying, mainly shifting within scope among 0.0 and 0.6 within interval declines (most obviously at the middle of 2008) and marginal raises.

Figure 7: Conditional correlation coefficient among IGBM and NASDAQ100 returns



The reporting ability of multivariate GARCH model for PX_R and NASDAQ100_R is lower with regard to amount of statistical significant coefficients represented within the table below. The results exhibit that conditional variance of PX returns is substantially influenced by the past conditional variance. The effect of its own conditional variability is grater for PX_R than for NASDAQ100_R (0.884 versus 0.856) and lower than IGBM_R (0.932). NASDAQ100_R is more affected by its own past shocks than PX_R (0.144 versus

0.085). On the other hand, PX_R is more affected by its own past shocks than IGBM (0.085 versus 0.059). Furthermore, conditional variance of PX_R is directly influenced by the past shock in NASDAQ100, anyway this variability spillover is very small (0.002).

Czech stock market shows statistically significant, but relatively low, nearly irrelevant, variability spillover from US stock exchange.

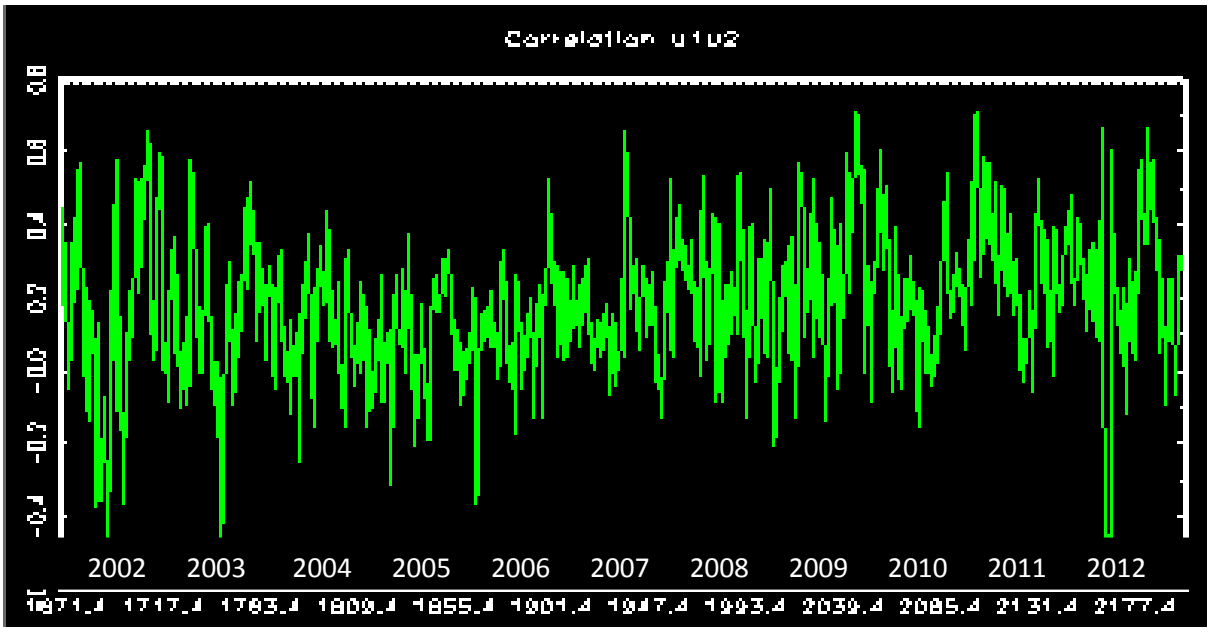
Table 6: Bivariate GARCH coefficients valuations for PX and NASDAQ100 returns

PX	constant term	$\varepsilon_{1}^{2}{}_{,t-1}$	$\varepsilon_1\varepsilon_{2,t-1}$	$\varepsilon_{2}^{2}{}_{,t-1}$	$h_{11,t-1}$	$h_{12,t-1}$	$h_{22,t-1}$
$h_{11,t}$	0.00000100	**0.08491**	0.02244	**0.00148**	**0.88435**	-0.02915	**0.00024**
$h_{22,t}$	0.00000241	0.002809	-0.04024	0.14410	0.00028	0.03071	0.85563
$h_{12,t}$	0.0000006	-0.01544	0.10857	0.01461	0.01561	0.86961	-0.01434

Notes: the pattern involves 2653 observations from 02.01.2002 to 20.03.2012; Creator's computations in JMulTi based on Reuters 3000 Xtra Terminal data

By analyzing the level of conditional correlation among PX_R and NASDAQ100_R we infer that the shift of conditional correlation coefficient is fairly fluctuating, exhibiting low levels and yet showing negative correlation. The conditional correlation coefficient among PX_R and NASDAQ100_R exhibits greater variability than the conditional correlation coefficient among IGBM_R and NASDAQ100_R.

Figure 8: Conditional correlation coefficient among PX and NASDAQ100 returns



Despite the prior multivariate GARCH models give several common and fairly interesting results, we would be cautious with carrying out final implications. The presenting skill of the models is relatively poor like effect of the consequences of residual diagnostics tests. Substantial ARCH effects yet stay into residual of all models which is verified by multivariate ARCH-LM test. Furthermore, Jarque-Bera test verifies the rejection of the null hypothesis for normality of the residuals for both models. Moreover, the residuals in the models contain autocorrelation. These results are presented in Table 4.

Figure 9: Q-Q plot for residuals of IGBM and NASDAQ returns

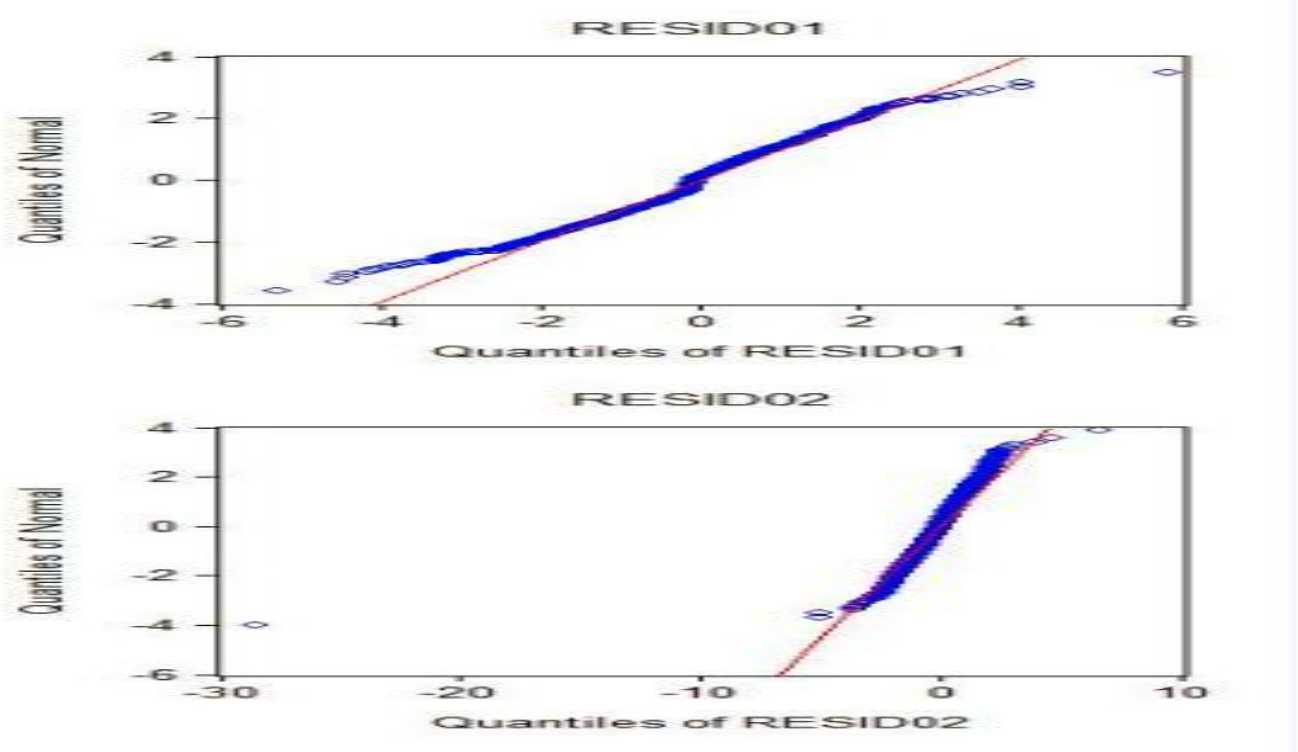
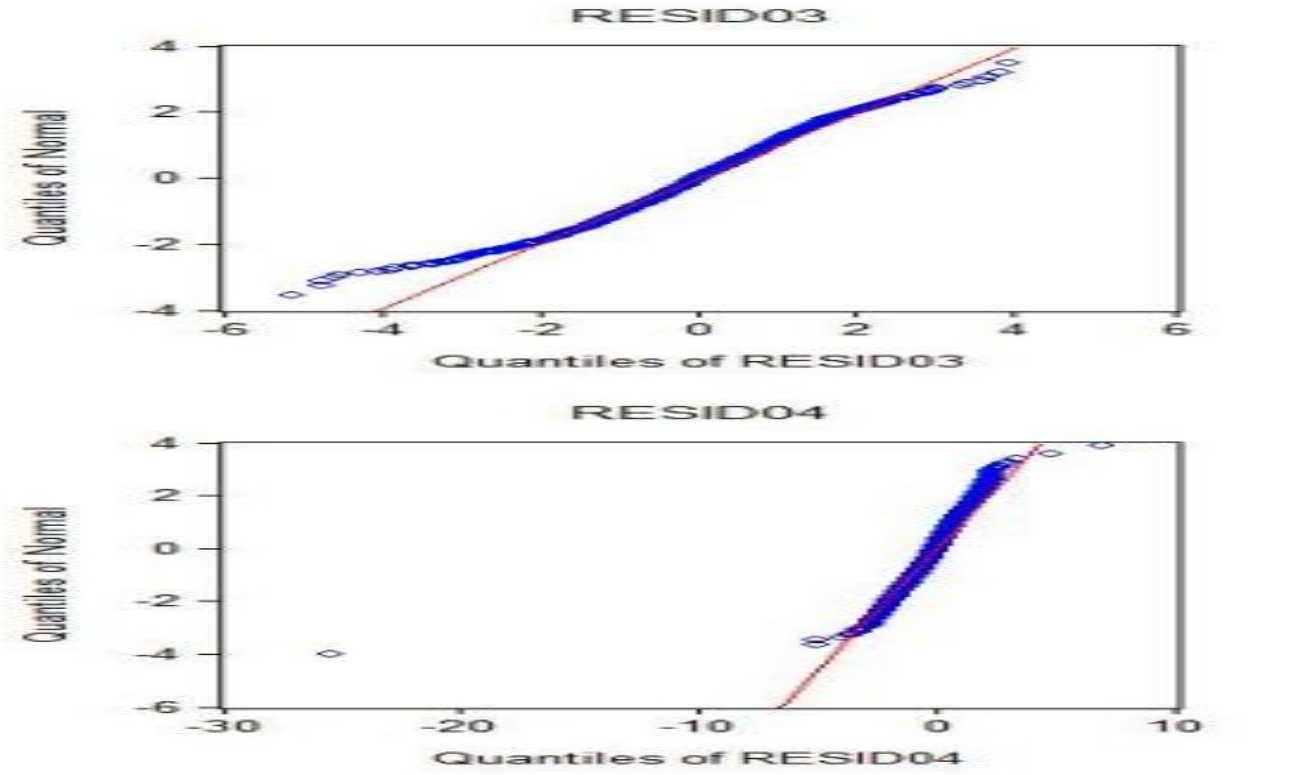


Figure 10: Q-Q plot for residuals of PX and NASDAQ returns



CHAPTER 6

6. Conclusion

The incentive for the thesis is studying the effect of the financial crisis on stock markets of the Czech Republic and Spain. We employ multivariate BEKK-GARCH model to analyze volatility spillovers and transmissions from US stock market to Czech and Spain stock markets.

The multivariate GARCH models results show statistically significant, but relatively small, almost irrelevant volatility spillovers from US stock market to the stock markets of Czech Republic and Spain.

The BEKK-GARCH specification exhibits that the conditional variance is significantly influenced by past conditional variance. Furthermore, it shows that the conditional variance is also significantly influenced by past shocks.

The plots of the conditional correlation coefficients among the stock markets of Czech Republic and Spain, and US stock market exhibit variation of the coefficients in the range of -0.2-0.6. However, the coefficient for Czech Republic indicates more fluctuation than the coefficient for Spain. The conditional correlation coefficient among Czech stock market and US stock market is fairly volatile, showing low levels and even negative correlation.

Nevertheless, we should be reserved about the conclusions of the multivariate GARCH model results owing to inconvenient diagnostics tests.

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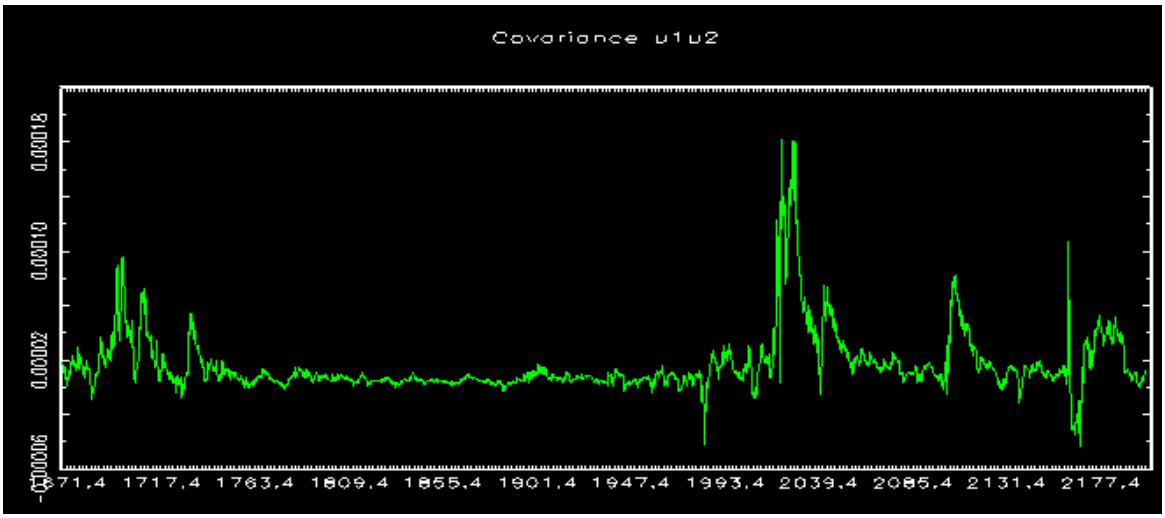
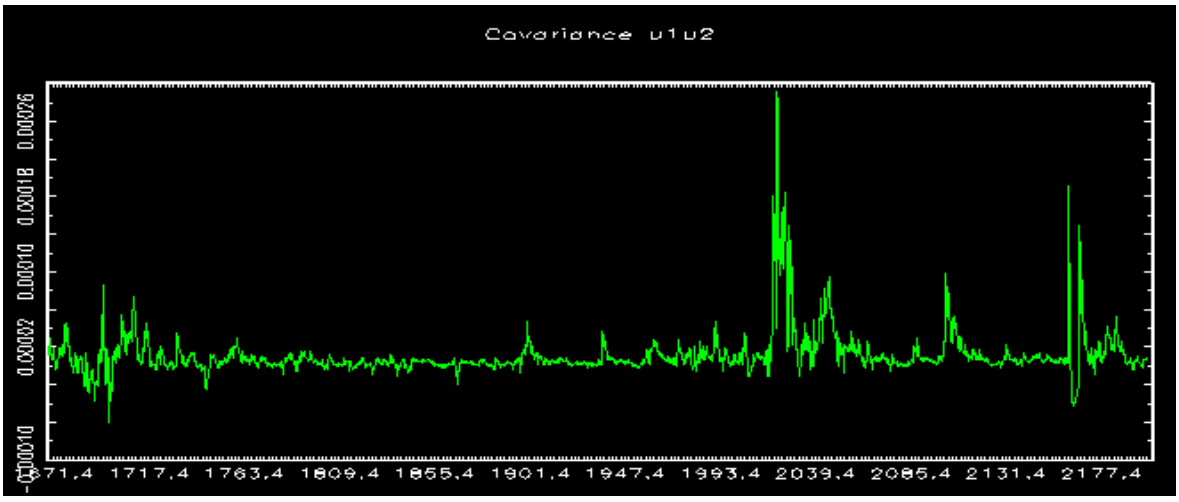
Appendix

Figure A.11: Conventional Covariance Processes form Multivariate GARCH models

Cov(IGBM_R, NASDAQ100_R)



Cov(PX_R, NASDAQ_R)



Note: Creator's computations in JMulTi based on Reuters 3000 Xtra Terminal data